

WHAT IS CLAIMED IS:

1. A transceiver for processing code division multiple access signals received through at least one multipath propagation channel to produce at least one relative frequency error estimate, comprising:

a processor for receiving and processing the signals using the local frequency reference oscillator to obtain representative complex numerical samples for processing;

channel estimators for correlating the complex numerical samples with shifts of a locally generated despreading code and producing a number of complex channel estimates, each

corresponding to a different delayed ray of the at least one multipath propagation channel;

frequency error estimators for computing a frequency error estimate for each ray based on successive values of a respective one of the channel estimates; and

at least one summer for performing a weighted summation of the frequency error estimates to provide at least one relative frequency error estimate.

2. The transceiver of claim 1, wherein the relative frequency error estimate is used to control the frequency of a local frequency reference oscillator.

3. The transceiver of claim 1, wherein the frequency error estimator computes the frequency error estimate by multiplying the current value of the respective channel estimate with the complex conjugate of a previous value of the same channel estimate and using the product as the frequency error estimate for the respective ray.

4. The transceiver of claim 2, wherein the relative frequency error estimate is used to control the frequency of the local frequency reference oscillator in such a direction as to reduce the relative frequency error estimate.

5. The transceiver of claim 4, further comprising an integrator for integrating the relative frequency error estimate to produce a control signal for controlling the frequency of the reference oscillator.

6. The transceiver of claim 2, wherein the local frequency reference oscillator is used to control a transmit frequency.

7. The transceiver of claim 1, wherein the channel estimator correlations are made using the despreading code of a pilot signal.

8. The transceiver of claim 2, further comprising a rake combiner for despreading a
5 desired signal using shifts of a locally generated wanted signal despreading code to produce one complex sample per data symbol per shift and for performing a weighted summation of the complex samples per shift using weighting factors based on the channel estimates to produce a rake-combined value for each data symbol.

10 9. The transceiver of claim 8, further comprising a decoder for decoding the per-symbol rake-combined values using a soft error correction decoder to reproduce wanted information bits.

10 10. The transceiver of claim 9, further comprising an error detection decoder for
15 performing an error check on the decoded information bits and to generate an error or no-error indication, wherein the relative frequency error estimate is only used to control the local reference oscillator when a no-error indication is generated.

20 11. The transceiver of claim 10, wherein the local frequency reference is used to control a transmit frequency.

12. The transceiver of claim 8, wherein the locally generated despreading code is a pilot code, and the locally generated data despreading code is a different code.

25 13. The transceiver of claim 8, wherein the locally generated despreading code is a segment of the locally generated data despreading code during a period of time when the data symbols are equal to known pilot symbols.

30 14. The transceiver of claim 2, wherein the signals used to control the frequency of the transceiver are received from one base station.

15. The transceiver of claim 2, wherein the at least one summer produces at least one relative frequency error estimate separately for each base station.

16. A method for processing code division multiple access signals received through at least one multipath propagation channel to produce at least one relative frequency error estimate, comprising the steps of:

receiving and processing the signals using the local frequency reference oscillator to
5 obtain representative complex numerical samples for processing;

correlating the complex numerical samples with shifts of a locally generated despreading code and producing a number of complex channel estimates, each corresponding to a different delayed ray of the at least one multipath propagation channel;

10 computing a frequency error estimate for each ray based on successive values of a respective one of the channel estimates; and

performing at least one weighted summation of the frequency error estimates to provide at least one relative frequency error estimate.

17. The method of claim 16, further comprising using the at least one relative
15 frequency error estimate to control the frequency of a local frequency reference oscillator.

18. The method of claim 16, wherein the step of computing includes multiplying the current value of the respective channel estimate with the complex conjugate of a previous value of the same channel estimate and using the product as the frequency error estimate for the
20 respective ray.

19. The method of claim 17, wherein the relative frequency error estimate is used to control the frequency of the local frequency reference oscillator in such a direction as to reduce the relative frequency error estimate.
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20. The method of claim 19, further comprising integrating the relative frequency error estimate to produce a control signal for controlling the frequency of the reference oscillator.

30 21. The method of claim 17, further comprising using the local frequency reference oscillator to control a transmit frequency.

22. The method of claim 16, wherein the channel estimator correlations are made using the despreading code of a pilot signal.

23. The method of claim 17, further comprising despread-
ing a desired signal with a rake combiner using shifts of a locally generated wanted signal despread-
ing code to produce one complex sample per data symbol per shift and performing a weighted summation of the complex
samples per shift using weighting factors based on the channel estimates to produce a rake-
5 combined value for each data symbol.

24. The method of claim 23, further comprising decoding the per-symbol rake-
combined values using a soft error correction decoder to reproduce wanted information bits.

10 25. The method of claim 24, further comprising performing an error check on the
decoded information bits and to generate an error or no-error indication, wherein the relative
frequency error estimate is only used to control the local reference oscillator when a no-error
indication is generated.

15 26. The method of claim 25, wherein the local frequency reference oscillator is used
to control the transceiver to transmit on a desired channel frequency.

27. The method of claim 23, wherein the locally generated despread-
ing code is a pilot code, and the locally generated data despread-
ing code is a different code.

20 28. The method of claim 23, wherein the locally generated despread-
ing code is a segment of the locally generated data despread-
ing code during a period of time when the data
symbols are equal to known pilot symbols.

25 29. The method of claim 17, wherein the signals used to control the frequency
of the transceiver are received from one base station.

30 30. The method of claim 17, wherein frequency error estimates are computed
separately for each base station.

31. A transceiver for processing code division multiple access signals received
through at least one multipath propagation channel to produce at least one relative frequency
error estimate, comprising:

a processor for receiving and processing the signals using the local frequency reference oscillator to obtain representative complex numerical samples for processing;

despreaders for different delayed rays of the multipath channel for correlating the numerical samples with different shifts of a locally generated despread code over symbol

5 intervals to produce streams of complex despread values corresponding to each ray and successive symbol interval;

frequency error correctors for correcting frequency errors on each of the despread value streams by progressively rotating the phase angle of successive despread values at a rate given by an associated frequency error integral;

10 channel estimators for processing the frequency-corrected despread value streams to produce complex channel estimates for each ray;

frequency error estimators for determining a frequency error estimate for each ray by processing successive values of the channel estimates for the corresponding ray; and

at least one combiner for combining the frequency error estimates to produce at least one
15 relative frequency error estimate.

32. The transceiver of claim 31, wherein the at least one relative frequency error estimate is used to control the frequency of a local frequency reference.

20 33. The transceiver of claim 32, further comprising inner loop integrators for integrating respective frequency error estimates to produce integrated frequency errors.

34. The transceiver of claim 33, wherein the at least one combiner adds the frequency error estimates and computes a relative frequency error estimate and integrates the frequency
25 error estimate using an outer loop integrator to produce the control signal.

35. The transceiver of claim 32, wherein the local frequency reference oscillator is used to control a transmit frequency.

30 36. The transceiver of claim 32, further comprising a rake combiner for despread a desired signal using shifts of a locally generated wanted signal despread code to produce one complex sample per data symbol per shift and for performing a weighted summation of the complex samples per shift using weighting factors based on the channel estimates to produce a rake-combined value for each data symbol.

37. The transceiver of claim 36, further comprising a decoder for decoding the per-symbol rake-combined values using a soft error correction decoder to reproduce wanted information bits.

5 38. The transceiver of claim 37, further comprising an error detection decoder for performing an error check on the decoded information bits and to generate an error or no-error indication, wherein the relative frequency error estimate is only used to control the local reference oscillator when the no-error indication is generated.

10 39. The transceiver of claim 31, wherein the signals are received from one base station.

40. The transceiver of claim 31, wherein the combiners produce frequency error estimates separately for each base station.

15 41. A method for processing code division multiple access signals received through at least one multipath propagation channel to produce at least one relative frequency error estimate, comprising the steps of:

receiving and processing the signals using the local frequency reference oscillator to
20 obtain representative complex numerical samples for processing;

correlating the numerical samples with different shifts of a locally generated despreading code over symbol intervals to produce streams of complex despread values corresponding to each ray and successive symbol interval;

correcting frequency errors on each of the despread value streams by progressively
25 rotating the phase angle of successive despread values at a rate given by an associated frequency error integral;

processing the frequency-corrected despread value streams to produce complex channel estimates for each ray;

determining a frequency error estimate for each ray by processing successive values of
30 the channel estimates for the corresponding ray; and

combining the frequency error estimates to produce at least one relative frequency error estimate.

42. The method of claim 41, further comprising using the at least one relative frequency error estimate to control the frequency of a local reference frequency oscillator.

43. The method of claim 42, further comprising integrating respective frequency error estimates using inner loop integrators to produce integrated frequency errors.

44. The method of claim 42, wherein the step of combining includes adding the frequency error estimates and obtaining a relative frequency error estimate and integrating the relative frequency error estimate using an outer loop integrator to produce the control signal.

45. The method of claim 42, further comprising using the local frequency reference oscillator to control a transmit frequency.

46. The method of claim 42, further comprising despreading a desired signal with a rake combiner using shifts of a locally generated wanted signal despreading code to produce one complex sample per data symbol per shift and performing a weighted summation of the complex samples per shift using weighting factors based on the channel estimates to produce a rake-combined value for each data symbol.

47. The method of claim 46, further comprising decoding the per-symbol rake-combined values using a soft error correction decoder to reproduce wanted information bits.

48. The method of claim 47, further comprising performing an error check on the decoded information bits and to generate an error or no-error indication, wherein the relative frequency estimate is only used to control the local reference oscillator when the no-error indication is generated.

49. The method of claim 41, wherein the signals are received from one base station.

50. The method of claim 41, wherein the frequency error estimates are determined separately for each base station.

51. The transceiver of claim 32, further comprising:

an inner loop integrator for integrating the frequency error estimate to produce inner loop integral values; and

an outer loop integrator for integrating the inner loop integral values to produce a control signal to control the local frequency reference oscillator to a value based on the received signal.

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52. The transceiver of claim 36, further comprising an error correction and detection decoder for soft-decoding a block of the rake-combined values to provide an error indication for successively recurring block intervals.

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53. The transceiver of claim 52, wherein the outer loop integrator integrates the inner loop integral values only for blocks for which the error indication is indicative of no errors, and the inner loop integrator integrates the frequency error estimate only for blocks for which the error indication is indicative of no errors.

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54. The transceiver of claim 52, wherein the combiner processes frequency error estimates corresponding to blocks of symbols that have been error correction and detection decoded and which have an associated error indication indicative of no errors.

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55. The method of claim 42, further comprising:
integrating the frequency error estimates using an inner loop integrator to produce inner loop integral values; and
integrating the inner loop integral values using an outer loop integrator to produce a control signal to control the local frequency reference oscillator to a value based on the received signal.

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56. The method of claim 46, further comprising soft-decoding a block of the rake-combined values to provide an error indication for successively recurring block intervals.

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57. The method of claim 56, wherein the step of integrating comprises integrating inner loop integral values only for blocks for which the error indication is indicative of no errors, and the step of integrating using an inner loop integrator integrates the frequency error estimates only for blocks for which the error indication is indicative of no errors.

58. The method of claim 56, wherein the step of combining processes frequency error estimates corresponding to blocks of symbols that have been error correction and detection decoded and which have an associated error indication indicative of no errors.

5 59. The transceiver of claim 2, further comprising an outer loop integrator for integrating the frequency estimates to produce a control signal to control the local frequency reference oscillator to a value based on the received signal.

60. The transceiver of claim 1, further comprising a rake-combiner for combining
10 and decoding the despread values to decode unknown data symbols.

61. The transceiver of claim 60, wherein the rake-combiner comprises an error correction and error detection decoder to produce an error indication for the decoded symbols.

15 62. The transceiver of claim 59, wherein the combiner adds the real parts of the per-ray frequency error estimates to obtain a real sum and adding the imaginary parts to produce an imaginary sum and computing the two-argument arctangent of the real and imaginary sum.

63. The method of claim 17, further comprising:
20 integrating the relative frequency error estimate using an outer loop integrator to produce a control signal; and
controlling the frequency of the local frequency reference oscillator using the control signal.

25 64. The method of claim 16, further comprising the step of rake-combining and decoding the despread values to decode unknown data symbols.

65. The method of claim 64, wherein the decoding comprises error correction and error detection decoding to produce an error indication for the decoded symbols.

30 66. The method of claim 63, wherein the combining step includes adding the real parts of the per-ray frequency error estimates to obtain a real sum and adding the imaginary parts to produce an imaginary sum and computing the two-argument arctangent of the real and imaginary sum.

67. The transceiver of claim 36, further comprising a rake-combiner for rake-combining and decoding the despread values to decode unknown data symbols.

68. The transceiver of claim 67, wherein the rake-combiner comprises error
5 correction and error detection decoder to produce an associated error indication for the decoded symbols.

69. The transceiver of claim 31, wherein the combiner adds the real parts of the per-ray frequency error estimates to obtain a real sum and adding the imaginary parts to produce an
10 imaginary sum and computing the two-argument arctangent of the real and imaginary sum.

70. The method of claim 41, further comprising rake-combining and decoding the despread values to decode unknown data symbols.

71. The method of claim 70, wherein the decoding comprises error
15 correction and error detection decoding to produce an associated error indication for the decoded symbols.

72. The method of claim 41, wherein the combining step includes adding the real
20 parts of the per-ray frequency error estimates to obtain a real sum and adding the imaginary parts to produce an imaginary sum and computing the two-argument arctangent of the real and imaginary sum.

73. An apparatus for estimating a frequency error between a local frequency
25 reference of a receiver and carrier frequencies of one or more transmitters, comprising:
frequency error estimators for estimating frequency errors separately for each transmitter; and

a combiner for combining the frequency error estimates to produce at least one relative frequency error estimate.

74. The apparatus of claim 73, further comprising integrating the combined
30 frequency error estimates.

75. A method for estimating a frequency error between a local frequency

reference of a receiver and carrier frequencies of one or more transmitters, comprising the steps of:

estimating frequency errors separately for each transmitter; and

combining the frequency error estimates to produce at least one relative frequency error

5 estimate.

76. The method of claim 75, further comprising integrating the combined frequency error estimates.